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A Comparison of Capacitive and Electric-field based Human Fingerprint Readers

The Basic Transducer Physics

If instantaneous electronic fingerprint recognition is to become a widely used tool for human identification, it must work well for almost everyone in the population. The wide variety of finger and skin conditions seen in the world population, combined with the wide variety of environments in which a sensor must operate, make this a non-trivial requirement.

Considerable engineering effort, expended over the last several decades, has produced a variety of surface based technologies for reading real-time (a.k.a.: live scan) fingerprint patterns. While many of these technologies are able to acquire useful fingerprint images from most of the criminal population (composed almost entirely of youthful males), all of these devices suffer from an inability to acquire useful fingerprint pattern data from significant other segments of the human population as a whole. The optical scanners that currently dominate the live scan fingerprint market often cannot acquire useful data from people with surfaced based issues such as skin that is dry, thickly callused, or worn smooth by mechanical or chemical means. These devices are also ineffective in situations where finger surfaces are contaminated with dirt, oil, or other substances; or those dried out from exposure to chemicals or other environmental factors.

To get past the issues associated with acquiring prints from the skin's surface, it was necessary to develop an entirely new approach through E-Field Technology. E-Field Technology™ is the fourth evolution of fingerprinting technologies and the first that is not limited by the the skin's exterior shortcomings. E-Field Technology™ is being implemented through FingerLoc™ by employing an antenna array sensor.

The AuthenTec fingerprint sensor, FingerLoc, was specifically designed to side step surface issues to read fingerprint patterns from the entire population, under a wide variety of conditions. It is a semiconductor device that uses small electric fields to detect an image of the fingerprint ridges and valley pattern where it originates. Its pattern detection technologies can capture useful fingerprint images from nearly everyone by reading the patterns from beneath the skin surface. This is in marked contrast with all other fingerprint sensors, like optical and DC capacitive which read the patterns at the actual skin surface.

DC capacitive sensors are silicon, surface based technology that use a matrix of small metal plates to detect spatial electrical variations representative of the fingerprint patterns. This type of technology has many limitations. E-Field Technology has unique ways of using coherent electric fields to reconstruct sharp, clear fingerprint patterns. This technology gives the sensor advantages in image quality, (especially on difficult-to-image fingers), ability to acquire, and in allowing thicker protective coatings.

The DC capacitive sensor array

The typical electronic fingerprint sensor is a silicon integrated circuit containing an array of capacitive sensor plates similar to those illustrated in Figure 1. Variations of this type of device have been described in patent materials dating back at least to the early 1970s. Each sensor plate produces a capacitance measurement whose value becomes the gray-scale value of an image pixel at that location in a bitmap image. In a typical realization, the capacitance of each pixel is measured individually by depositing a fixed charge on that pixel. The static voltage generated by that charge is proportional to the pixel's capacitance to its surroundings. The patterns generated by this structure are illustrated in Figure 1. For finger geometries, the flux lines originate from the energized sensing plate to the skin immediately adjacent to the sensing plate, and terminate primarily on adjacent, inactive sensor plates or on the substrate.

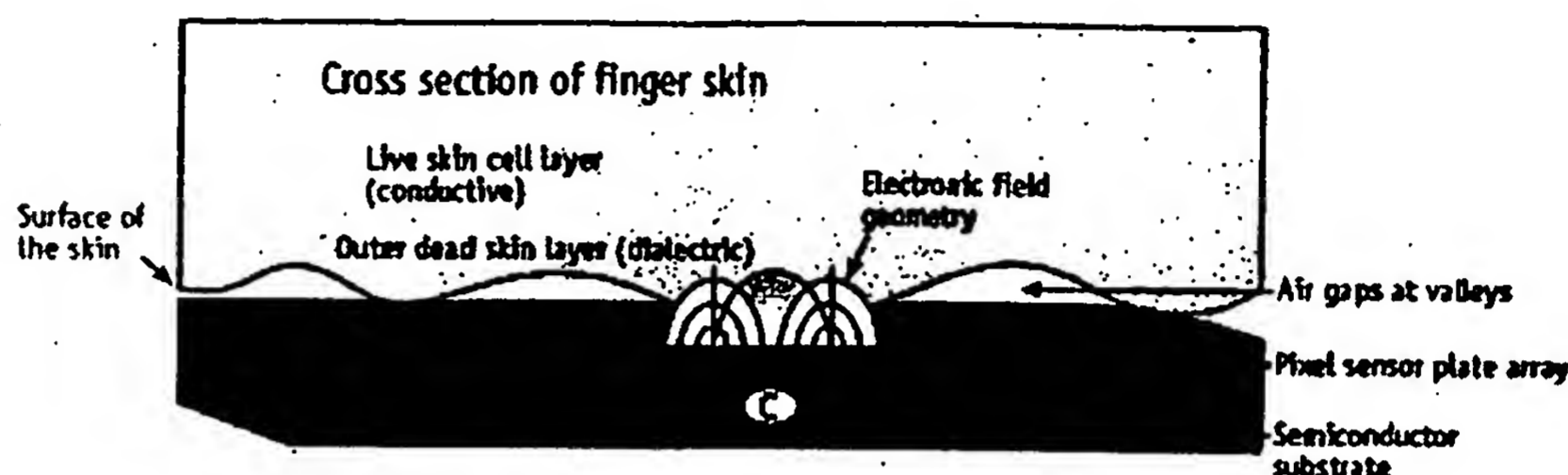


Figure 1: Classic capacitive fingerprint sensor- cross section of sensor array reading finger skin

An advantage of this design is its simplicity. A disadvantage of this design is the spherical electric field geometries generated around each pixel sensor plate, when it is energized and read. In this field geometry, each pixel's sensing area overlaps the sensing areas of neighboring pixels. This overlap can considerably exceed the size of the pixel's sensor plate. The effect appears as crosstalk between adjacent sensors; reducing the device's actual imaging resolution to about half the theoretical resolution of its sensor matrix density.

A variation of this classic capacitive design uses 2-plates per capacitive pixel sensor to improve the device's spatial resolution. This design limits the size of each pixel's sensing region by adding a second conductive plate to each pixel's sensing mechanism. Electronic circuitry, such as an op amp feedback loop, measures the capacitance between the two plates while minimizing the effects of capacitance between the sensing plates and their environment.

In both of the designs described above, the depth of field penetration beyond the sensor surface is very small. It is so small that these sensing devices differentiate ridges from valleys by detecting the difference in dielectric constant between the air gap in the valleys and the dead skin on the surface of the ridges. For young, healthy, clean fingers these approaches work adequately. Problems arise when less than optimal surface skin conditions occur. When the finger is dirty or worn, there often is no remaining air gap at all. When the finger surface is very dry, the difference in dielectric constant between the dry skin and the air gap is significantly reduced. In elderly people, the skin becomes loose and the normal finger pressure applied to the sensor easily flattens the surface ridges and valleys. All this translates into an unpredictable and sometimes inadequate ability to acquire useful fingerprint images, limiting the sensor's applications.

Electric-field antenna array

In contrast to capacitive sensors which do not allow you to "read" the ridge and valley patterns of everyone, AuthenTec has developed a unique patented E-Field Technology array sensor. The field antenna array devices detect the ridges and valleys in the live layer of skin cells located beneath the dead cells that make up the skin surface. The antenna array measures these subsurface features by generating and detecting linear field geometries. These fields penetrate the skin surface, in fact

the fields originate from the conductive live layer of skin cells beneath the skin surface. This is in contrast to the spherical or tubular field geometries, generated by DC capacitive sensors, which only fringe the very top surface of the skin.

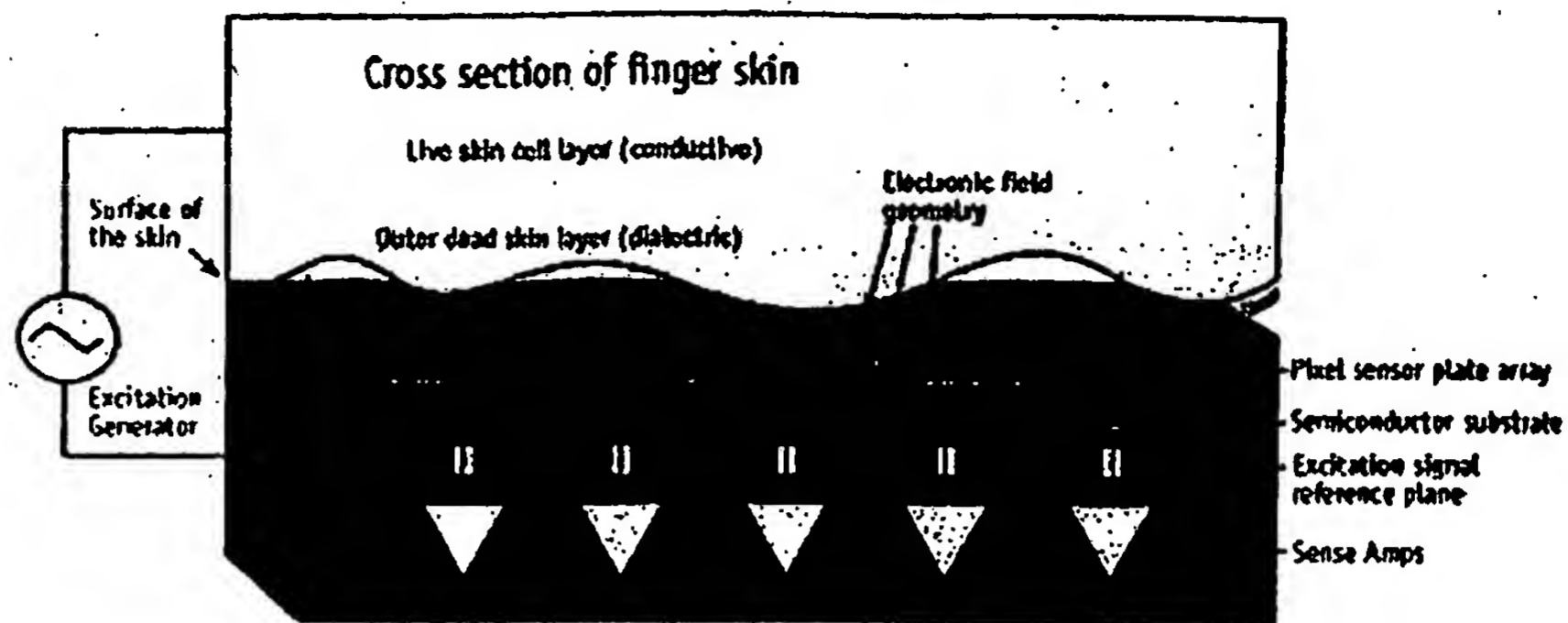


Figure 2: Electric-field antenna array fingerprint sensor cross section of sensor array reading finger skin

In practice, a small RF field is applied between a conductive layer buried inside a silicon chip and the conductive layer just beneath the surface of the finger skin as illustrated in Figure 2. The fields formed between these conductive surfaces replicate the shape of the conductive skin layer in the amplitude of the AC field. Tiny sensor plates inserted just beneath the surface of the semiconductor, and above the continuous conductive layer, measure the field potential contours. Amplifiers buried directly beneath each pixel sensor plate, convert the potentials on the plates to voltages representing the fingerprint pattern. These signals are further conditioned and then multiplexed out of the sensor array.

E-Field Technology antenna array devices do not depend on a surface feature such as the air gap between the sensor and the fingerprint valley to detect that valley. As a result, many types of fingers that are difficult or impossible to image adequately using optical or DC capacitive sensors (see previous discussion of difficult fingers), can be successfully imaged using E-Field Technology.

The E-Field Technology antenna array technology has other advantages as well. For rugged real-world applications, the penetrating linear field geometry allows these devices to have much thicker protective coatings without loss of sensitivity than is capable with capacitive sensors. The sensing mechanism is very adaptable. The sensor's operating points (such as operating frequencies, gain, E-field dispersion, etc.) can be dynamically varied by real-time controls, to optimize detection of various types of fingerprint features and to reject noise and undesired artifacts. This is referred to as Dynamic Optimization.